Arsenic-Contaminated Soils

"This game is like swimming in syrup"

Tim McCarver

(Describing Game 3 of 2005 World Series)

Prepared for

MTCA Science Advisory Board

December 15, 2005

What are these levels being used for?

Strategy is the articulation of targets, and plans to achieve those targets, in light of available resources and constraints. Strategic planning is done not in the service of plan writing, but to facilitate the making of real choices. Strategy serves as the source of perspective and proportion. It enables one to differentiate between big problems and small ones; to separate significant issues from trivial ones; to conserve resources and coordinate behavior. It gives subordinates a clear sense of what their superiors are really trying to achieve.

Marc Landy, Marc Roberts, and Stephen Thomas
From "The Environmental Protection Agency:
Asking the Wrong Questions"

Moderate Levels of Arsenic & Lead Ecology 2003 Working Definition

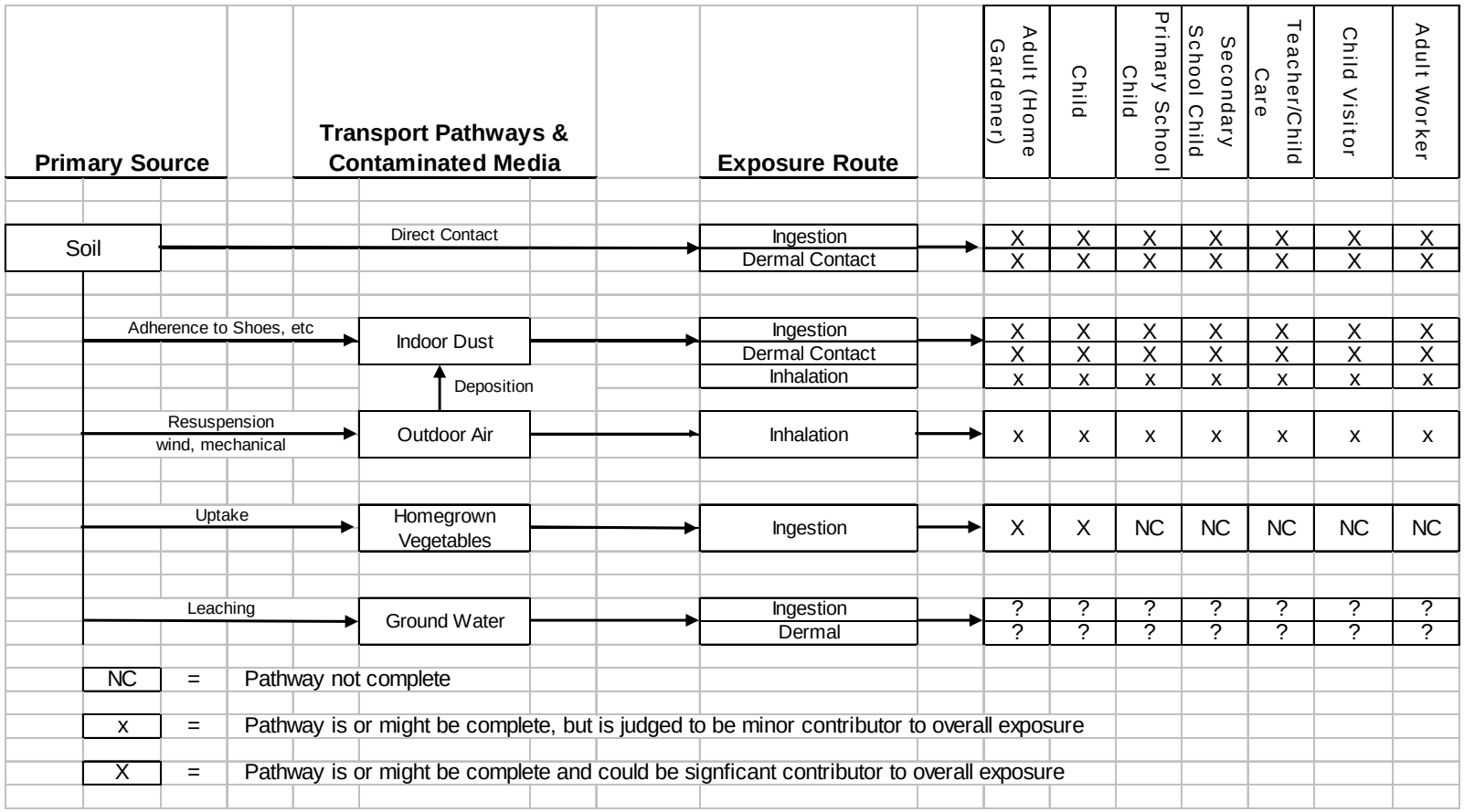
	Lead	Arsenic
Residential Areas	250 – 500	20 - 100
Schools & Child Care Facilities	250 – 700	20 - 100
Commercial Facilities & Parks	250 – 1000	20 - 200

Establishing Working Definition for Arsenic-Contaminated Soils

$$\text{Action Levels} = f(\text{Toxicity, Exposure, Policy})$$

- **Ecology considered three measures when characterizing human health risks**
  - **Lifetime Cancer Risks**
  - **Non-Cancer Health Effects (Chronic Exposure)**
  - **Non-Cancer Health Effects (Less-Than-Lifetime Exposure)**
- **Ecology considered two main pathways of exposure when characterizing human health risks**
  - **Soil Ingestion**
  - **Dermal Contact**

What exposure pathways did Ecology consider when evaluating exposure to arsenic-contaminated soils?



Primary Source	Transport Pathways & Contaminated Media	Exposure Route	Adult (Home Gardener)	Child	Primary School Child	Secondary School Child	Teacher/Child Care	Child Visitor	Adult Worker
Soil	Direct Contact	Ingestion	X	X	X	X	X	X	X
		Dermal Contact	X	X	X	X	X	X	X
	Adherence to Shoes, etc → Indoor Dust	Ingestion	X	X	X	X	X	X	X
		Dermal Contact	X	X	X	X	X	X	X
		Inhalation	x	x	x	x	x	x	x
	Deposition → Outdoor Air	Inhalation	x	x	x	x	x	x	x
	Resuspension wind, mechanical → Outdoor Air	Inhalation	x	x	x	x	x	x	x
	Uptake → Homegrown Vegetables	Ingestion	X	X	NC	NC	NC	NC	NC
	Leaching → Ground Water	Ingestion	?	?	?	?	?	?	?
		Dermal	?	?	?	?	?	?	?

NC	=	Pathway not complete
x	=	Pathway is or might be complete, but is judged to be minor contributor to overall exposure
X	=	Pathway is or might be complete and could be signficant contributor to overall exposure

Non-Cancer Risk Model (chronic exposure)

$$\text{Hazard Quotient} = \frac{\text{Average Daily Dose (ADD)}}{\text{Reference Dose (chronic oral)}}$$

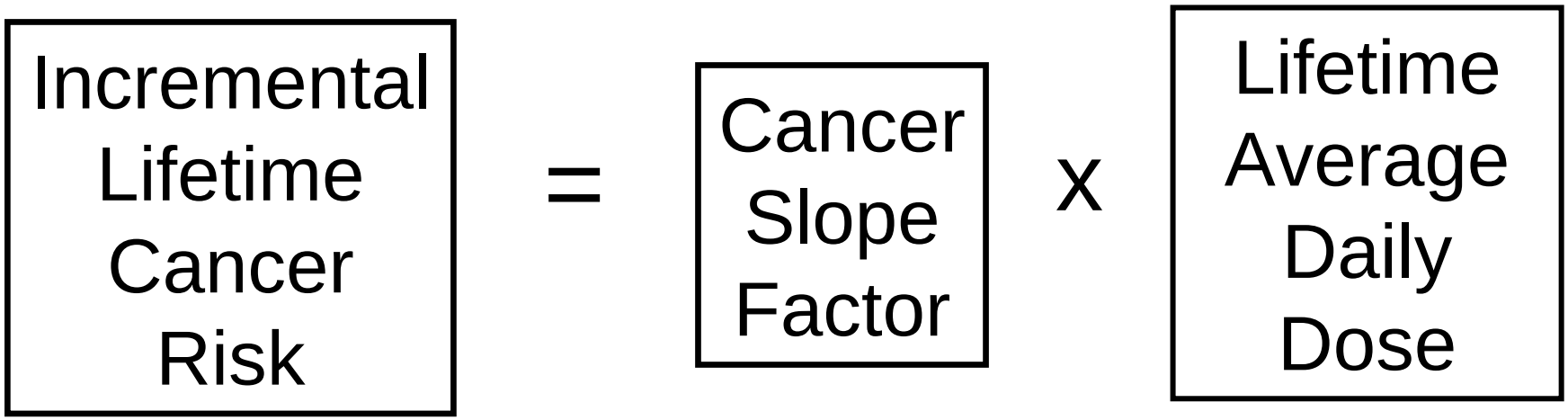
What exposure measure did Ecology use when evaluating non-carcinogenic health risks?

$$\text{ADD}_{\text{mg/kg/day}} = \frac{SC * EF * ED * [(SIR * AB1) + (SA * AF * ABS)]}{BW * AT * UCF}$$

Where:

SC	=	Soil concentration (mg/kg)
EF	=	Frequency of exposure (0.3 – 1.0)
ED	=	Duration of exposure (6 years)
SIR	=	Soil ingestion rate (200 mg/day)
AB1	=	GI absorption rate (1.0)
SA	=	Dermal surface area (2,200 cm^2)
AF	=	Adherence factor (0.2 mg/cm^2-day)
ABS	=	Dermal absorption factor (0.03)
BW	=	Body weight (16 kg)
AT	=	Averaging time (6 years)
UCF	=	1,000,000 mg/kg

Cancer Risk Model



What exposure measure did Ecology use when evaluating carcinogenic risks?

$$\text{LADD}_{\text{mg/kg/day}} = \frac{SC * EF * ED * [(SIR * AB1) + (SA * AF * ABS)]}{BW * AT * UCF}$$

Where:

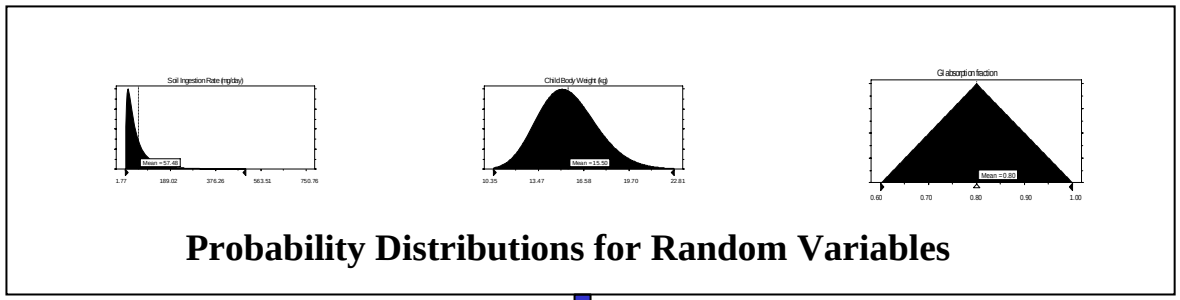
- SC = Soil concentration (mg/kg)
- EF = Frequency of exposure (0.3 – 1.0)
- ED = Duration of exposure (6 years)
- SIR = Soil ingestion rate (200 mg/day)
- AB1 = GI absorption rate (1.0)
- SA = Dermal surface Area (2,200 cm^2)
- AF = Adherence factor (0.2 mg/cm^2-day)
- ABS = Dermal absorption factor (0.03)
- BW = Body weight (16 kg)
- AT = Averaging time (75 years)
- UCF = 1,000,000 mg/kg

Exposure Point Estimates

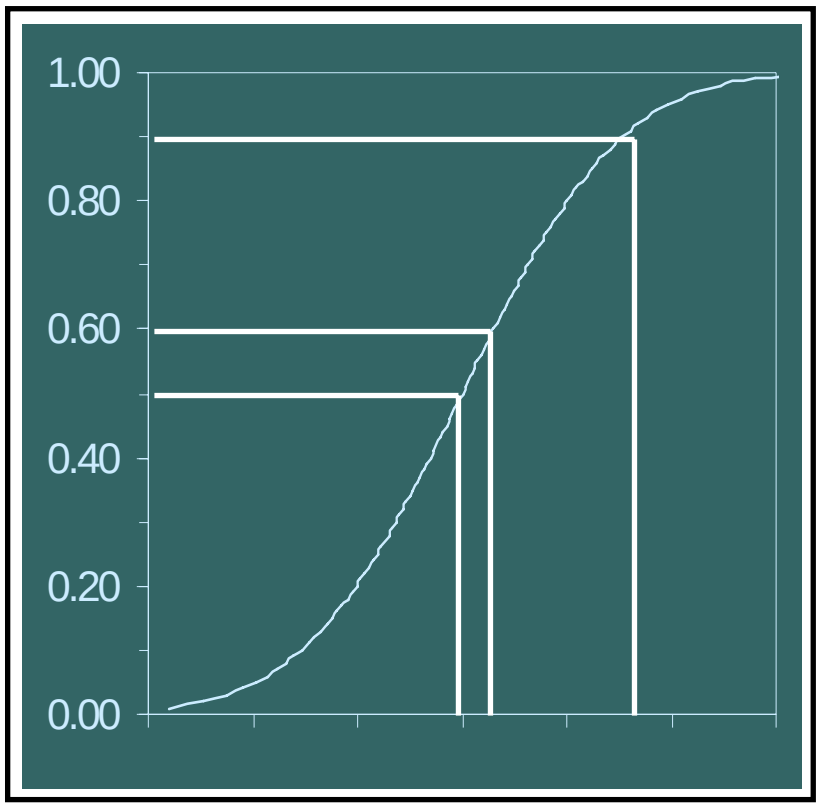
	LADD (mg/kg/day)	ADD mg/kg/day
MTCA - Residential	1.1E-04	1.3E-03
MTCA – Schools & Child Care Facilities	7.5E-05	9.3E-04
MTCA - Parks	3.1E-05	3.6E-04

Estimating Variability in Exposure Using 1-D Monte Carlo Simulation

- **Input probability distributions**
- **Select random values and calculate exposure**
- **Repeat for many iterations**



Monte Carlo Simulation Results



Average Daily Dose

Point Estimate = 1.3E-03

Median = 2.6E-04

Mean = 3.2 E-04

90th Percentile = 6.2E-04

95th Percentile = 8.8E-04

How does the selection of the SIR distribution impact simulation results?

Soil Ingestion Rate Distribution	Mean	90th	95th	% Variance
Oregon DEQ (1998)	3.0E-04	5.9E-04	7.8E-04	90%
EPA Region 8 (2001)	4.8E-04	7.8E-04	9.3E-04	90%
EPA Pesticide Program (2003)	3.2E-04	6.2E-04	8.8E-04	90%

How does soil size fraction influence exposure estimates?

SIR Distribution	Mean	90th	95th	% Variance
EPA (2003) w/o Soil Enrichment Factor	3.2E-04	6.2E-04	8.8E-04	90% (SIR) 8% (AF) 2% (other)
EPA (2003) with Soil Enrichment Factor	5.5E-04	1.1E-03	1.6E-03	81% (SIR) 10% (SEF) 6% (AF) 3% (other)

Toxicological Parameters

- Cancer slope factor (oral exposure)
- Reference dose (chronic oral exposure)
- Reference dose (less-than-lifetime oral exposure)
- Cancer slope factor (inhalation exposure)

Schools and Child Care Exposure Scenario Estimated Hazard Quotient Values at Arsenic Concentration of 100 mg/kg

Schools and Child Care Exposure Scenario Range of Estimated Hazard Quotient Values Associated with Exposure to Arsenic at 100 mg/kg			
Exposure Estimate (mg/kg/day)		Chronic Oral Reference Dose (mg/kg/day)	
		3.0E-04	1.2E-04
MTCA Point Est.	9.1E-04	3.0E+00	7.6E+00
MCE (Mean)	2.2E-04	7.5E-01	1.9E+00
MCE (90th)	4.3E-04	1.4E+00	3.6E+00
MCE (95th)	6.2E-04	2.1E+00	5.1E+00

Residential Exposure Scenario Estimated Hazard Quotient Values at Arsenic Concentration of 100 mg/kg

Residential Exposure Scenario Range of Estimated Hazard Quotient Values Associated with Exposure to Arsenic at 100 mg/kg			
Exposure Estimate (mg/kg/day)		**Chronic RfD (mg/kg/day)**	
		3.0E-04	**1.2E-04**
MTCA Point Est.	1.3E-03	4.3E+00	1.1E+01
MCE (Mean)	3.2E-04	1.1E+00	2.7E+00
MCE (90th)	6.2E-04	2.1E+00	5.2E+00
MCE (95th)	8.8E-04	2.9E+00	7.3E+00

Non-Cancer Health Risks Summary

- Original hazard quotient estimates range from 0.5 to 4.3.
- Subsequent analyses generate hazard quotient values ranging from 1 to 18.
- Sources of uncertainty and variability:
  - Toxicological parameter(s);
  - Absorption;
  - Consumption of homegrown vegetables;
  - Arsenic concentrations in different soil size fractions;
  - Parameter variability.

Schools and Child Care Exposure Scenario Range of Estimated Upper Bound Cancer Risks at 100 mg/kg

School and Child Care Exposure Scenario Range of Estimated Incremental Cancer Risks Associated with Exposure to Arsenic at 100 mg/kg					
Exposure Estimate (mg/kg/day)		Cancer Slope Factor			
		1.5	3.7	5.7	9.4
MTCA Point Est.	7.5E-05	1.1E-04	2.8E-04	4.3E-04	7.1E-04
MCE (Mean estimate)	1.8E-05	2.7E-05	6.7E-05	1.0E-04	1.7E-04
MCE (90th)	3.5E-05	5.3E-05	1.3E-04	2.0E-04	3.3E-04
MCE (95th)	4.9E-05	7.4E-05	1.8E-04	2.8E-04	4.6E-04

Residential Exposure Scenario
Range of Estimated Upper Bound Cancer Risks at 100 mg/kg

Residential Exposure Scenario Range of Estimated Cancer Risks Associated with Exposure to Arsenic at 100 mg/kg					
Exposure Estimate (mg/kg/day)		Cancer Slope Factor			
		1.5	3.7	5.7	9.4
MTCA Point Est.	1.1E-04	1.7E-04	4.1E-04	6.3E-04	1.0E-03
MCE (Mean Estimate)	2.6E-05	3.9E-05	9.6E-05	1.5E-04	2.4E-04
MCE (90th)	5.0E-05	7.5E-05	1.9E-04	2.9E-04	4.7E-04
MCE (95th)	7.0E-05	1.1E-04	2.6E-04	4.0E-04	6.6E-04

Cancer Risks Summary

- Original cancer risk estimates at soil arsenic concentration of 100 mg/kg ranged from 4×10^{-5} to 2×10^{-4}.
- Subsequent analyses generated cancer risk estimates at 100 mg/kg ranging from 3×10^{-5} to 1×10^{-3}.
- Sources of uncertainty and variability:
  - Cancer slope factor;
  - Absorption;
  - Consumption of homegrown vegetables;
  - Arsenic concentrations in different soil size fractions;
  - Parameter variability.

Questions for the Science Advisory Board

- Are the methods and assumptions used by Ecology to characterize the health risks associated with arsenic-contaminated soils consistent with current scientific information?
  - Cancer slope factors
  - Reference doses
  - Methods and assumptions used to characterize exposure
  - Ground water impacts
  - Ecological risks

Questions for the Science Advisory Board (continued)

- Are the methods and assumptions used by Ecology to characterize the health risks associated with arsenic-contaminated soils consistent with current scientific information?
  - Cancer slope factors
  - Reference doses
  - Methods and assumptions used to characterize exposure
  - Ground water impacts
  - Ecological risks

What was the Board's response to Ecology's question on the cancer slope factor?

Environmental Protection Agency – Integrated Risk Information System (IRIS)	1.5 mg/kg/day^{-1} [skin cancer] 5.7 mg/kg/day^{-1} (Draft) [lung-bladder]
Environmental Protection Agency – Office of Drinking Water/Office of Pesticide Programs	3.7 mg/kg/day^{-1} [lung, bladder]
California Office of Environmental Health Hazard Assessment (OEHHA)	9.4 mg/kg/day^{-1} [lung, bladder]

What was the Board's response to Ecology's question on the chronic oral reference dose?

Source	Value
EPA Integrated Risk Information System	0.0003
ATSDR, Minimal Risk Level	0.0003
Consumer Product Safety Comm, (2003)	0.00008
California OEHHA (2004)	0.00012

What was the Board's response to Ecology's question on the reference dose for "less than lifetime" exposure?

Source	Value (mg/kg/day)
Washington Department of Health	0.005
ATSDR	0.005
EPA, Region VIII	0.015
EPA, Office of Pesticide Programs	0.0017

Arsenic Exposure Resulting from Incidental Soil and Dust Ingestion

- Is the assumption that incidental ingestion of soil and dust represents an important exposure pathway for children and adults consistent with current scientific information?
- Ecology has assumed this pathway is an important contributor to overall exposure to arsenic-contaminated soils.
  - Screening analysis
  - EPA guidance and site-specific assessments
  - Studies on soil ingestion and arsenic exposure
  - Scientific review committees
  - Uncertainty and variability

Arsenic Exposure Resulting from Dermal Contact

- Is the assumption that dermal contact with arsenic-contaminated soils represents an important exposure pathway for children and adults consistent with current scientific information?
- Ecology has assumed this is a complete pathway and could be an important contributor to overall exposure to arsenic-contaminated soils in some situations.
  - Screening analysis
  - EPA guidance and site-specific assessments
  - Studies on dermal contact and absorption of arsenic
  - Scientific review committees
  - Uncertainty and variability

Inhalation of Windblown Dust

- Is the assumption that inhalation of windblown dust is a minor contributor to overall exposure to arsenic-contaminated soils consistent with current scientific information?
- Ecology concluded that inhalation is of windblown dust is a complete pathway, but is likely to a be minor contributor to overall exposure to arsenic contaminated soils.
  - Screening level analyses
  - Results from other cleanup sites
  - Arsenic exposure studies
  - Uncertainty and variability

Homegrown Vegetables

- In evaluating arsenic-contaminated soils, Ecology did not quantify potential exposures resulting from the uptake of arsenic into homegrown vegetables due to uncertainties associated with estimating plant uptake. Is this approach consistent with current scientific information? ?
- Ecology has concluded that exposure resulting from the consumption of homegrown vegetables grown in arsenic-contaminated soils could represent an important exposure pathway, but did not quantify the potential exposures resulting from this pathway when establishing the working definition for arsenic-contaminated soils.
  - Screening level analyses
  - Results from other cleanup sites
  - Arsenic exposure studies
  - Uncertainty and variability

Methods and Assumptions Used to Characterize Exposure

- Are the methods, parameters and assumptions used in estimate exposure to arsenic-contaminated soils consistent with current scientific information?
- Ecology concluded that inhalation is of windblown dust is a complete pathway, but is likely to a be minor contributor to overall exposure to arsenic contaminated soils.
  - Consistency with MTCA rule
  - Consistency with EPA guidance and site-specific assessments
  - Conclusions/findings of scientific review panels
  - Uncertainty and variability

How do estimates using MTCA methods compare with estimates based on EPA guidance?

Average Daily Dose (ADD expressed as mg/kg/day) associated with Soil Ingestion/Dermal Contact at Arsenic Soil Concentration of 100 mg/kg		
Estimate	Central Tendency Estimate (CTE)	Reasonable Maximum Exposure (RME)
MTCA Residential (6 year child)	1.3E-03	
Vasquez Blvd-I-70 Site (6 year child)	4.0E-05	1.1E-04
Coeur d'Alene River Basin (6 year child)	3.4E-04	8.9E-04
Vasquez Blvd-I-70 Site (30 year child/adult)	5.6E-05	1.6E-04
Coeur d'Alene River Basin (30 year child/adult)	1.1E-04	2.1E-04

How do estimates using MTCA methods compare with estimates based on EPA guidance?

Lifetime Average Daily Dose (LADD expressed as mg/kg/day) associated with Soil Ingestion/Dermal Contact at Arsenic Soil Concentration of 100 mg/kg		
Estimate	Central Tendency Estimate (CTE)	Reasonable Maximum Exposure (RME)
MTCA Residential (6 year child)	1.1E-04	
Vasquez Blvd-I-70 Site (6 year child)	5.2E-06	4.8E-05
Coeur d'Alene River Basin (6 year child)	9.8E-06	7.6E-05
Vasquez Blvd-I-70 Site (30 year child/adult)	7.2E-06	6.9E-05
Coeur d'Alene River Basin (30 year child/adult)	1.4E-05	1.1E-04

Uncertainty & Variability Exposure Methods and Parameters

- Factors that may contribute to underestimating exposure
- Factors that may contribute to over-or underestimates
- Factors that may contribute to overestimating exposure

Additional Information to Complete Science Advisory Board Review?

- Information on the level and distribution of soil arsenic concentrations in Western and Eastern Washington
- Results of EPA's review/revisions of cancer slope factor
- Information on less-than-lifetime exposure and risk estimates (including children with pica behavior)
- Additional information on inhalation of windblown dust?
- Information on exposure resulting from home grown vegetables
- Information on concentrations in different soil size fractions
- Other?

Recommendations for Future Information Collection and Evaluation

- Are there specific information collection and analysis activities that the Board recommends Ecology undertake to address data gaps and uncertainties in the information used to estimate exposure and health risks associated with arsenic-contaminated soils?
  - Information on the level and distribution of soil arsenic concentrations in Western and Eastern Washington
  - Information on the uptake of arsenic into home grown vegetables
  - Information on arsenic concentrations in different soil size fractions
  - Other?

Next Steps

- Complete review of discussion materials
- Identify and prepare additional information to facilitate Board's review
- Compile Board's responses to Ecology's questions